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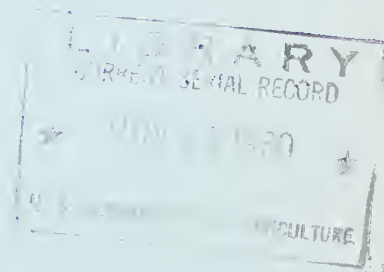
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AUGUST 1960

NORMAL YIELD TABLES

for Red Alder

by NORMAN P. WORTHINGTON
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U. S. DEPT. OF AGRICULTURE • FOREST SERVICE

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by

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FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

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INTRODUCTION

Increasing interest in the management of red alder (Alnus rubra) has created a need for reliable yield information. Existing yield tables for red alder^{1/} have been very useful as interim sources of information, but they are generally inadequate for current and prospective management needs. The advisory committee for the Station's Olympia Research Center, at the suggestion of several members, sponsored a subcommittee to promote the construction of new tables suitable for regionwide application. Through cooperative efforts of both public and private forestry organizations, the project was started in 1956.

This research paper has been prepared to make the newly derived tables available to Northwest foresters without delay. The narrative presentation is accordingly brief. A more complete report on the red alder yield study--including more adequate coverage of source data, analytical procedures, and application--is planned for future publication.

BASIC DATA

Field work for the red alder yield tables was begun in the summer of 1956 and completed in 1957. Altogether, data from 428 sample plots well stratified throughout northwestern Oregon, western Washington, and southern British Columbia were used in the yield table construction. A goal of 60 plots within each 10-year age class from 10 through 80 years was thus reasonably well attained. All plots conformed to the following specifications:

1. Pure stand, containing over 80 percent red alder by basal area.
2. Closed crown canopy, to give evidence of normality over the past 10 years.

^{1/} British Columbia Forest Service. Yield tables 1947. 7 pp. (plus tables). 1947. (Processed.)

Johnson, Herman M., Hanzlik, Edward J., and Gibbons, William H. Red alder of the Pacific Northwest: its utilization, with notes on growth and management. U.S. Dept. Agr. Bul. 1437, 46 pp., illus. 1926.

Lloyd, W. J. Unpublished empirical yield tables, U.S. Soil Conserv. Serv., Seattle, Wash. 1943.

Pope, R. B. Empirical yield tables--Douglas-fir subregion. 1954. (Unpublished report. Copy on file U.S. Forest Serv. Pac. NW. Forest and Range Expt. Sta., Portland, Oreg.)

3. Plot location restricted to a uniform part of the stand.
4. Plot size of 1/40 acre for stands under 10 years old, 1/10 acre for stands 10 to 20 years old, and 1/5 acre for stands over 20 years old.

Data taken for each plot included:

1. Diameter of all trees larger than 0.5 inch d.b.h., by species and 1-inch diameter classes.
2. Stand age, determined from breast-high increment borings of five trees in the upper canopy.
3. Total height of the five trees bored for age and of an additional five trees to fill out stand diameter range.

Site curves were developed from stem analyses of 43 felled and sectioned trees distributed throughout western Washington. The index stand age for the curve is 50 years, with stand age defined as breast-high age plus 2 years. This method of site indexing, involving multiple regression, was described by Bishop et al.^{2/}

Yield data were derived for the following stand characteristics:

1. Trees per acre
2. Basal area per acre
3. Diameter of average tree
4. Cubic feet per acre
5. Board feet per acre, Scribner rule

ANALYSIS PROCEDURE

Multiple regression analyses were used to calculate the formulas that express the basic relations of stand characteristics such as basal area, diameter, and volume to stand age and site index. Yield tables and figures were then derived from the formulas. Dependent variables in the regression analyses were basal area, average diameter, cubic volume, and board-foot-cubic-foot ratio (from which board-foot yields were calculated). Independent

^{2/}Bishop, Daniel M., Johnson, Floyd A., and Staebler, George R. Site curves for red alder. U.S. Forest Serv. Pac. NW. Forest and Range Expt. Sta. Res. Note 162, 7 pp., illus. 1958. (Processed.)

variables included first, second, and third powers of stand age; first and second powers of site index; and the product of stand age and site index. The most effective combinations of the independent variables were used in developing the final yield formulas, which are shown in footnotes to appropriate yield tables.

For three stand attributes--basal area, average diameter, and cubic volume--separate analyses were made for the following three stand segments:

1. All trees larger than 0.5 inch d. b. h.
2. All trees larger than 5.5 inches d. b. h.
3. All trees larger than 9.5 inches d. b. h.

Because of limited and naturally variable data, the regressions for the different stand segments invariably crossed. This problem of crossing was arbitrarily resolved by using the regression for the stand segment larger than 5.5 inches above the point of crossing. The age at which crossing occurred, called merging age, was found to depend on site index. This relationship is also shown in footnotes to appropriate yield tables.

Yield in board feet was developed by applying the board-foot--cubic-foot ratios determined from multiple regression to the calculated cubic-foot yield of trees larger than 9.5 inches d. b. h. Thus, a reasonable relation of board-foot to cubic-foot yields was assured. Equations used for calculating board-foot yields (footnotes, table 13) were obtained by multiplying the ratio formula by the appropriate cubic-volume yield formula.

APPLICATION

In using the tables to predict yields of specific stands, allowances should, of course, be made for inevitable differences between fully stocked conditions as represented by the tables and actual conditions as encountered in the forest. The tables are based on data from small plots, selected for normal stocking, and do not characterize stand conditions usually found over wide areas. Lower values than those in the tables should therefore be expected when yield data are applied to existing stands.

In comparing red alder yields with those of associated conifers, two additional factors should be recognized: (1) red alder stands usually contain more defect than conifer stands of comparable age; and (2) an 8-foot scaling length is the basis for board-foot yields of red alder, whereas a 16-foot scaling length is used for most conifers.

The "merging age" device, used in some tables to smooth out irregularities, should not affect practical application of the yield tables because the loss in accuracy is insignificant.

Blocks in tables indicate extent of the basic data.

FIGURE 1

Average total height of dominant
and codominant trees

TOTAL HEIGHT

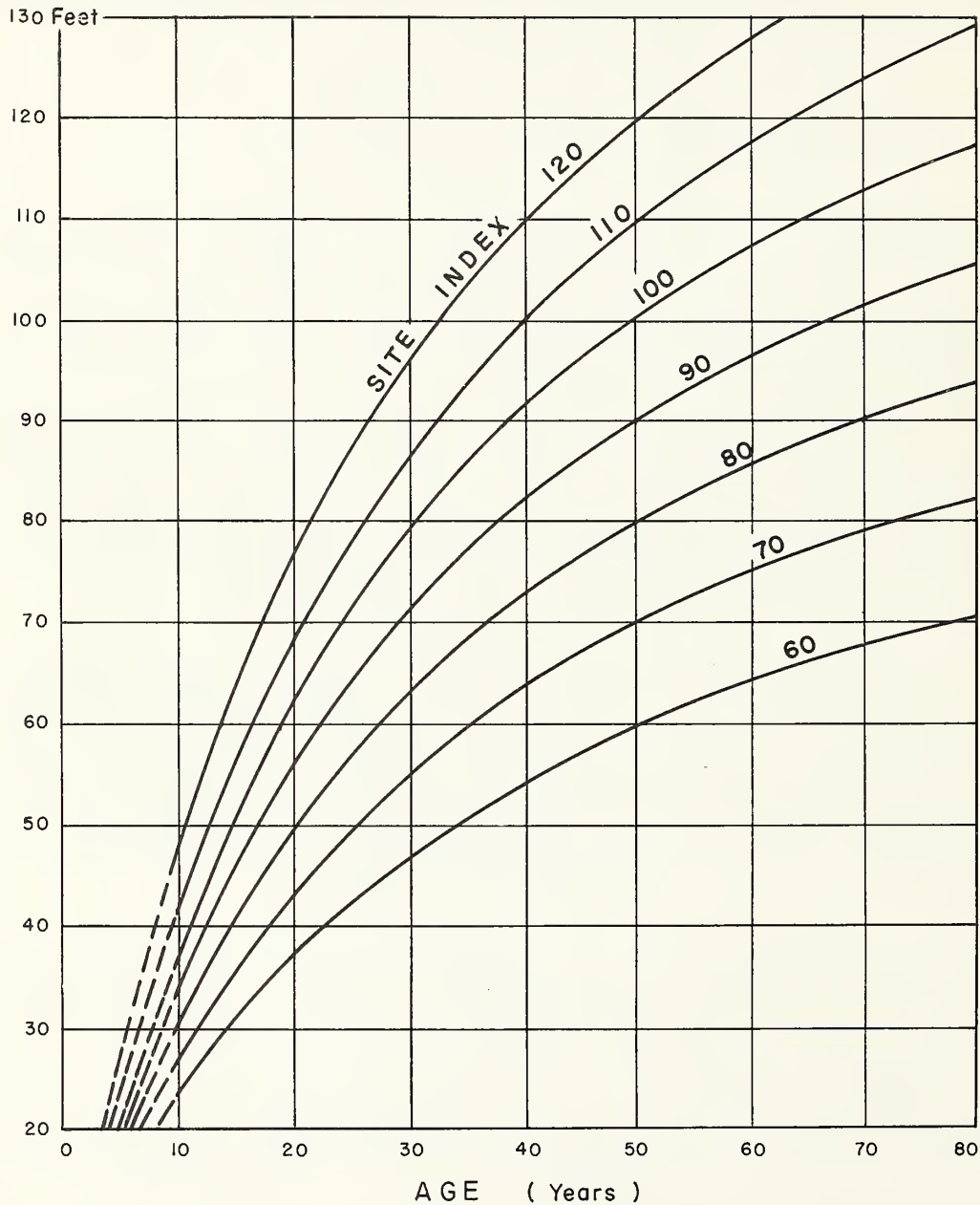


TABLE 1

Average total height of dominant
and codominant trees

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
	23	27	31	35	39	43	47
10	31	37	42	47	52	58	63
15	38	44	50	57	63	69	76
20	43	50	58	65	72	79	86
25	48	56	63	71	79	87	95
30	51	60	69	77	86	94	103
35	55	64	73	82	91	100	109
40	58	67	77	86	96	105	115
45	60	70	80	90	100	110	120
50	62	73	83	93	104	114	124
55	64	75	86	96	107	118	128
60	66	77	88	99	110	121	132
65	68	79	90	101	113	124	135
70	69	80	92	103	115	126	138
75	70	82	94	105	117	129	141
80							

Derived from the formula:

$$\text{Site index} = (0.60924 + 19.538/\text{age}) \text{ height};$$

where site index is for stand age 50.

FIGURE 2

Trees per acre--larger
than 0.5 inch d.b.h.

NUMBER OF TREES

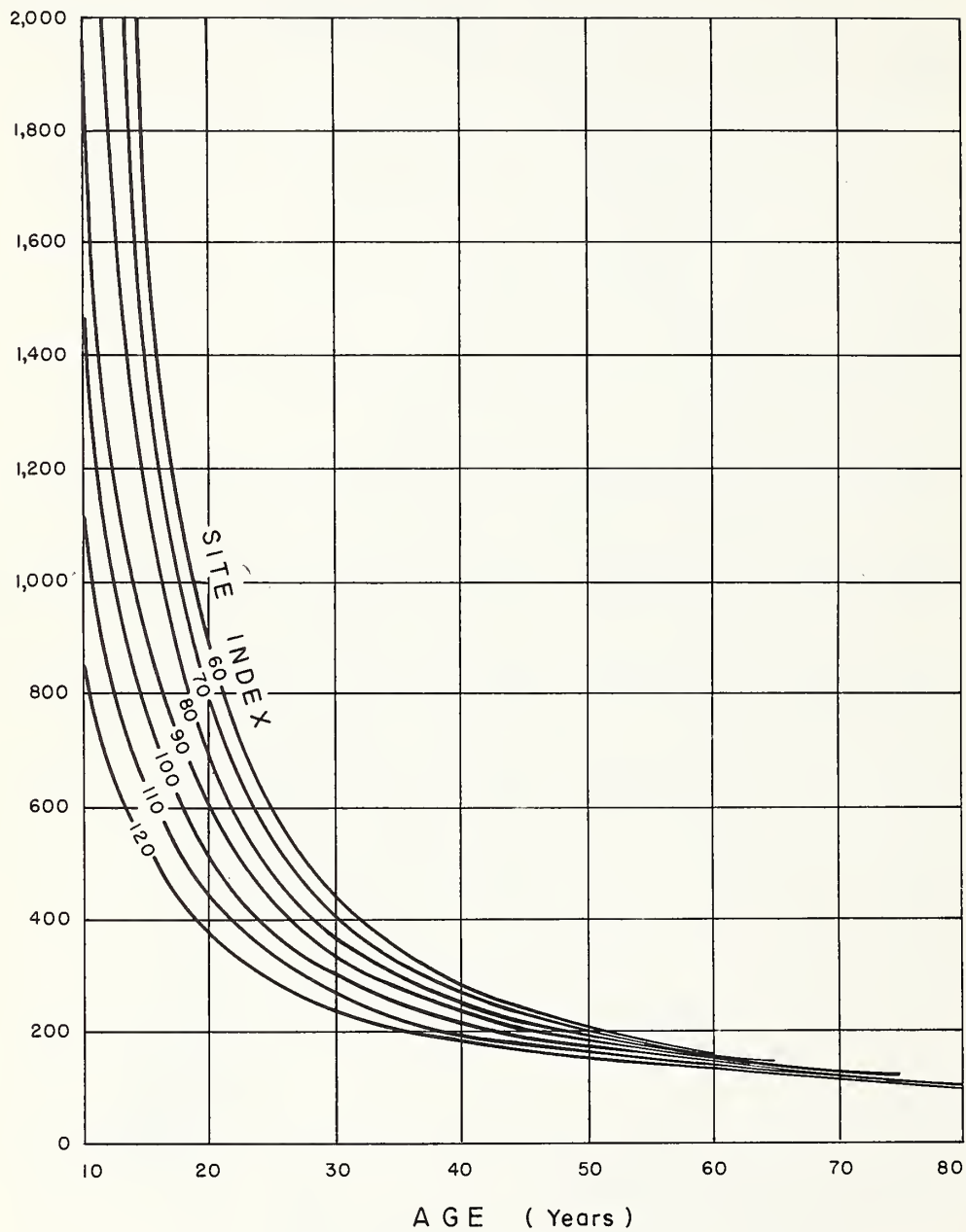


TABLE 2

Trees per acre--larger
than 0.5 inch d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
	<u>Number</u>						
10	4,742	3,531	2,613	1,964	1,469	1,111	851
15	1,702	1,410	1,171	956	779	643	528
20	919	808	695	674	512	441	376
25	609	543	486	432	378	334	291
30	445	404	368	333	300	267	239
35	345	321	296	272	248	225	202
40	282	265	247	231	212	194	184
45	239	229	218	205	190	178	169
50	209	203	196	184	172	165	157
55	173	172	169	165	159	151	144
60	157	157	154	150	145	139	133
65	--	141	139	137	132	128	122
70	--	--	126	124	121	117	112
75	--	--	--	112	109	106	102
80	--	--	--	--	98	96	93

Number of trees obtained by dividing total basal area by basal area of average tree.

FIGURE 3

Trees per acre--larger
than 5.5 inches d.b.h.

NUMBER OF TREES

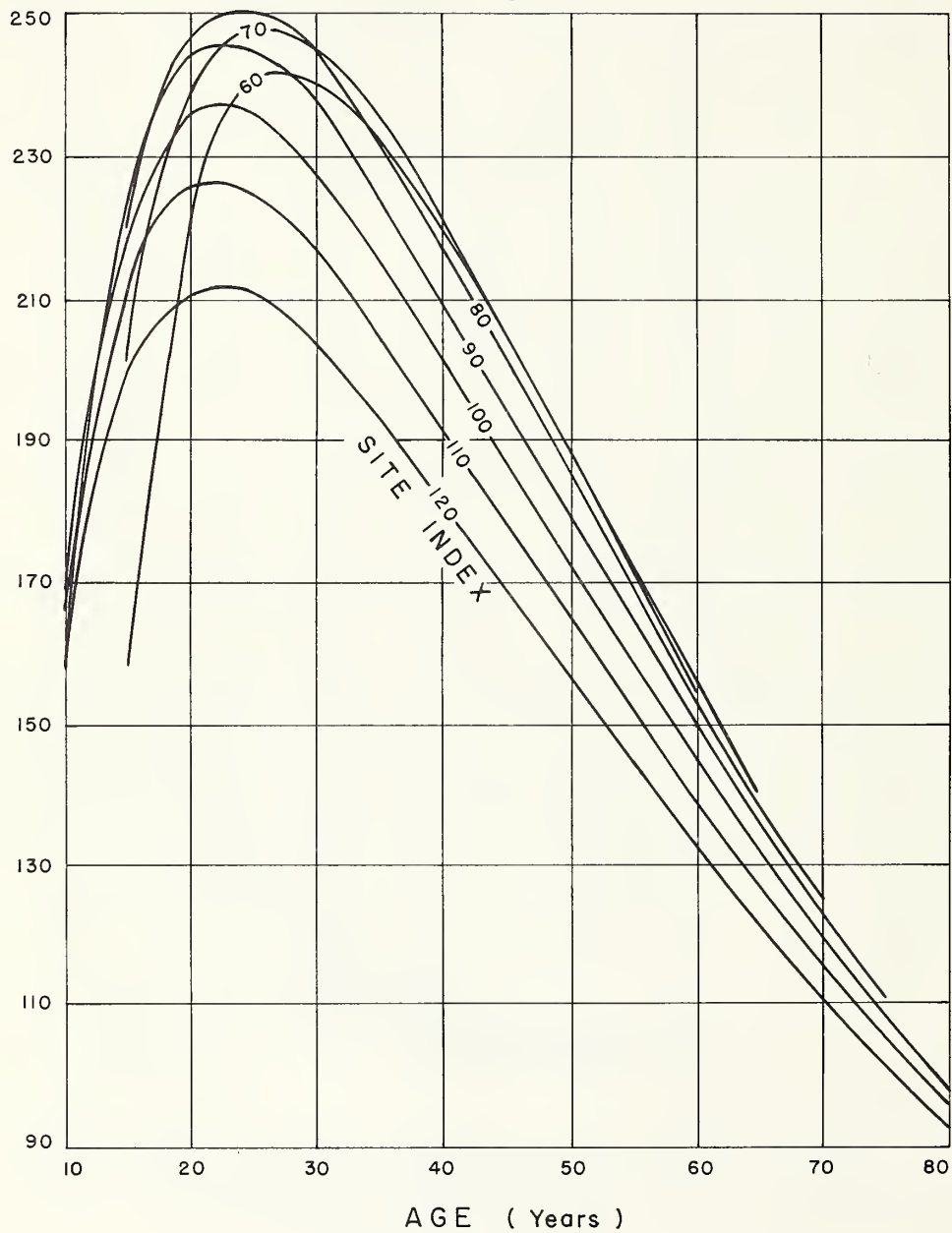


TABLE 3

Trees per acre--larger
than 5.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
	----- <u>Number</u> -----						
10	--	--	--	158	169	166	158
15	158	201	220	223	219	211	199
20	220	239	247	244	236	226	211
25	241	248	250	244	236	225	211
30	240	245	245	238	227	217	204
35	232	235	231	224	216	205	193
40	219	221	217	210	201	191	181
45	205	205	201	194	186	178	169
50	188	188	185	179	172	165	156
55	171	172	169	165	159	151	144
60	155	157	154	150	145	139	133
65	--	141	139	137	132	128	122
70	--	--	126	124	121	117	112
75	--	--	--	112	109	106	102
80	--	--	--	--	98	96	93

Number of trees obtained by dividing total basal area by basal area of average tree.

FIGURE 4

Trees per acre--larger
than 9.5 inches d.b.h.

NUMBER OF TREES

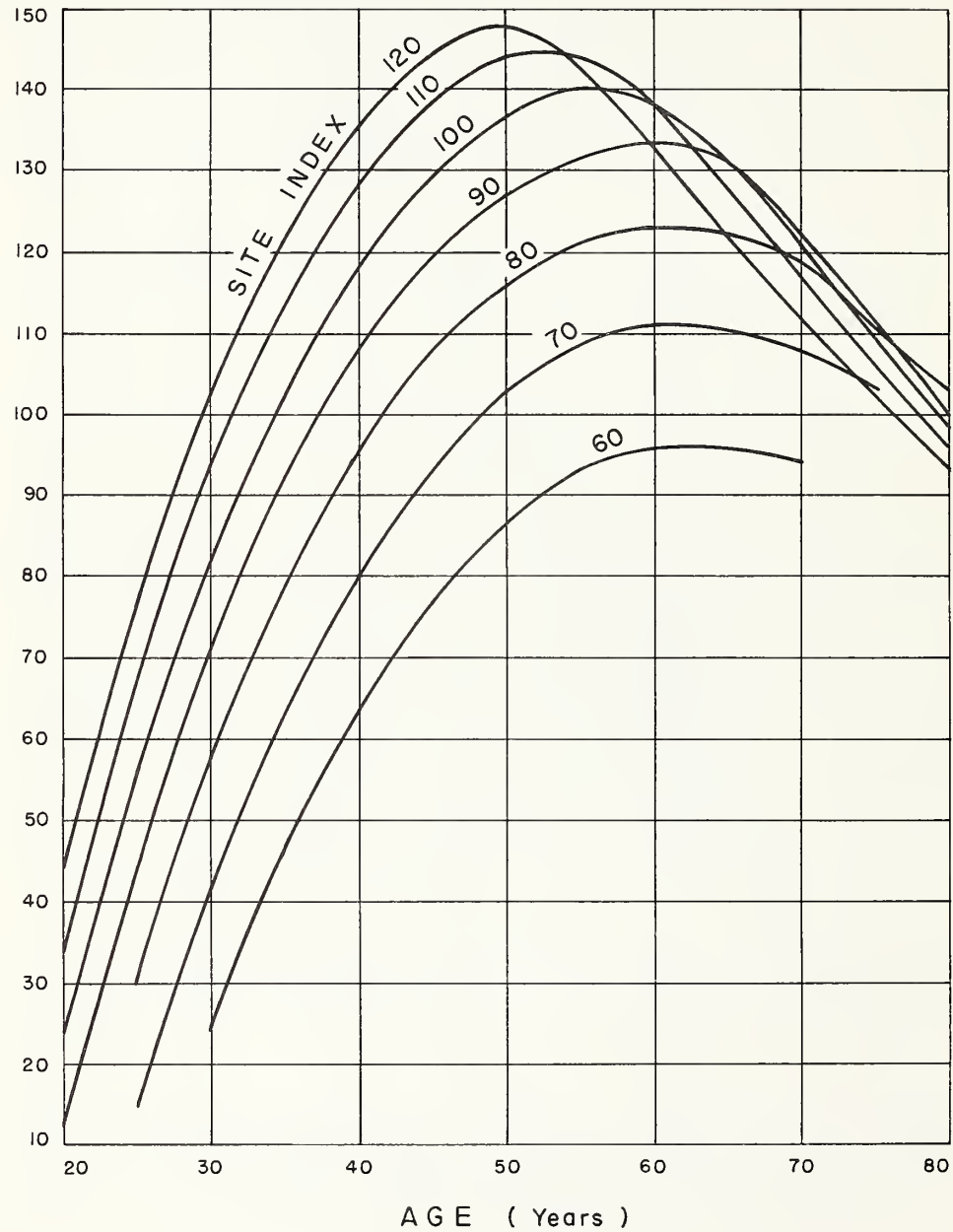


TABLE 4

Trees per acre--larger
than 9.5 inches d.b.h.

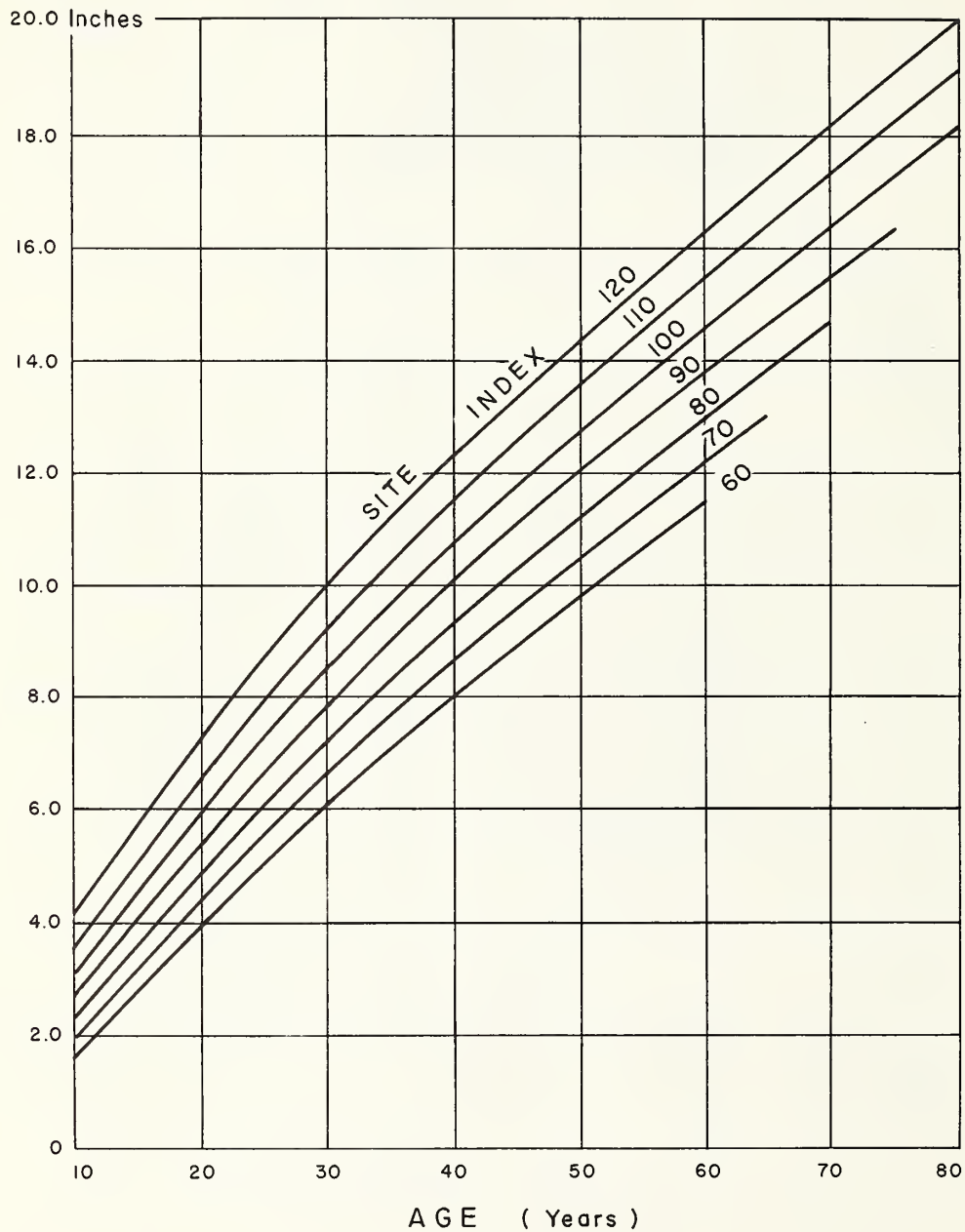
Age (years)	:	Site index (feet)						
	:							
	:	60	70	80	90	100	110	120
	:							
		----- <u>Number</u> -----						
20	--	--	--	12	24	34	44	
25	--	15	30	44	56	67	76	
30	24	41	57	70	82	93	102	
35	46	63	78	92	101	113	121	
40	63	80	95	108	118	128	135	
45	77	93	108	119	129	138	144	
50	86	103	116	127	136	144	148	
55	93	108	121	131	140	144	143	
60	96	111	123	132	138	138	133	
65	96	110	122	130	131	128	122	
70	94	108	119	122	121	117	112	
75	--	103	111	112	109	106	102	
80	--	--	103	100	98	96	93	

Number of trees obtained by dividing total basal area by basal area of average tree.

FIGURE 5

Diameter of average tree--
larger than 0.5 inch d.b.h.

DIAMETER



Diameter of average tree--
larger than 0.5 inch d.b.h.

$$\text{Merging age} = 6.75 + 1.3625(\text{site index}) - 0.009375(\text{site index})^2.$$

FIGURE 6

Diameter of average tree--
larger than 5.5 inches d.b.h.

DIAMETER

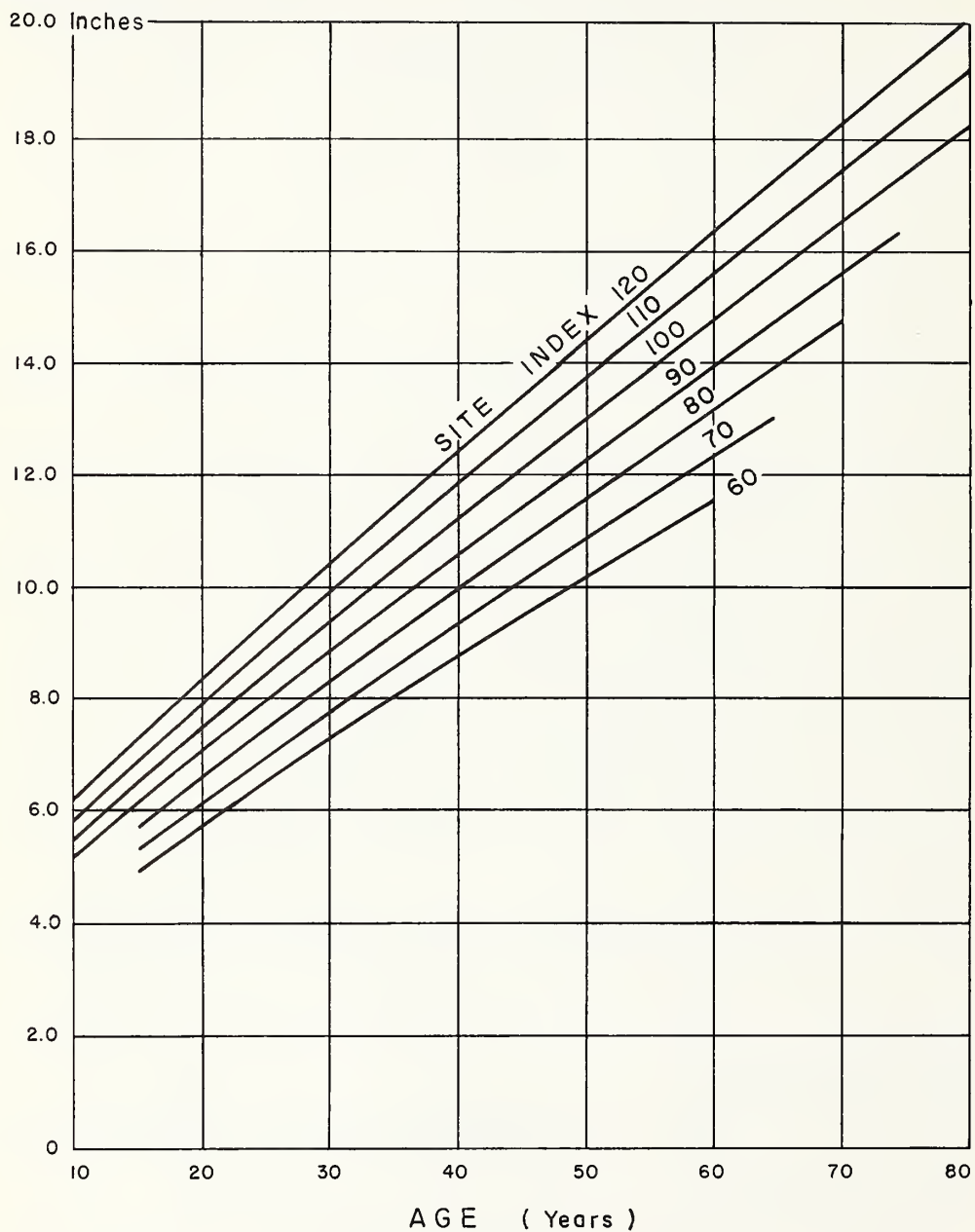


TABLE 6

Diameter of average tree--
larger than 5.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
	----- Inches -----						
10	--	--	--	5.2	5.5	5.8	6.2
15	4.9	5.3	5.7	6.1	6.5	6.9	7.2
20	5.7	6.1	6.6	7.0	7.4	7.9	8.3
25	6.5	6.9	7.4	7.9	8.4	8.8	9.3
30	7.2	7.7	8.3	8.8	9.3	9.8	10.3
35	7.9	8.5	9.1	9.7	10.2	10.8	11.4
40	8.7	9.3	9.9	10.5	11.1	11.7	12.4
45	9.4	10.1	10.7	11.4	12.0	12.7	13.4
50	10.1	10.8	11.5	12.2	12.9	13.6	14.3
55	10.8	11.6	12.3	13.1	13.8	14.6	15.3
60	11.5	12.3	13.1	13.9	14.7	15.5	16.3
65	--	13.0	13.9	14.7	15.5	16.4	17.2
70	--	--	14.6	15.5	16.4	17.3	18.2
75	--	--	--	16.3	17.2	18.2	19.1
80	--	--	--	--	18.1	19.1	20.0

$$\begin{aligned} \text{Diameter of average tree} = & 1.09 + 0.1057(\text{age}) - 0.000198(\text{age})^2 \\ & + 0.0247(\text{site index}) \\ & + 0.000911(\text{site index})(\text{age}). \end{aligned}$$

FIGURE 7

Diameter of average tree--
larger than 9.5 inches d.b.h.

DIAMETER

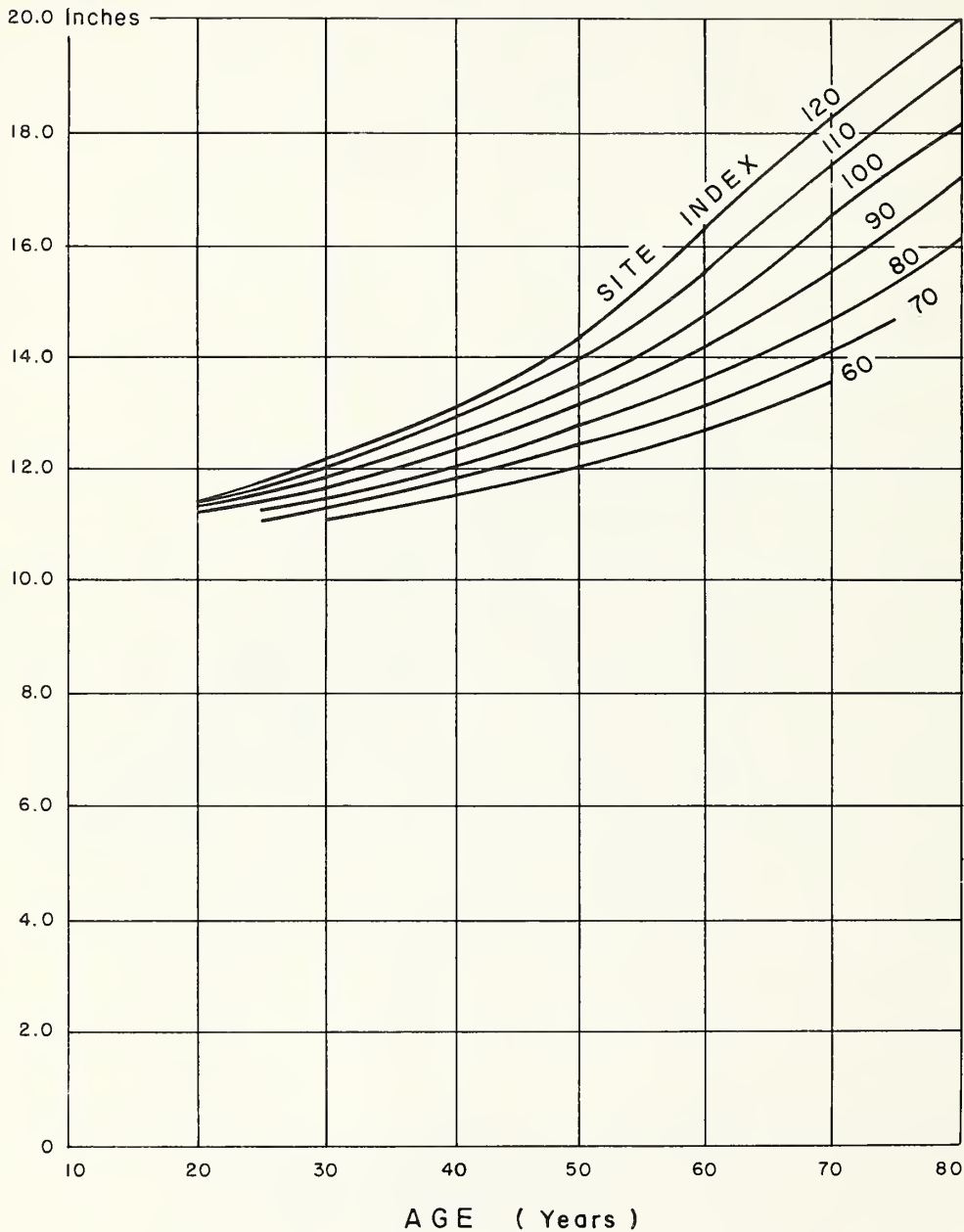


TABLE 7

Diameter of average tree--
larger than 9.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- Inches -----							
20	--	--	--	11.1	11.2	11.3	11.3
25	--	11.1	11.2	11.4	11.5	11.6	11.7
30	11.1	11.3	11.4	11.6	11.8	12.0	12.2
35	11.2	11.5	11.7	11.9	12.3	12.4	12.6
40	11.5	11.7	12.0	12.3	12.6	12.9	13.1
45	11.7	12.0	12.4	12.7	13.0	13.3	13.7
50	12.0	12.4	12.8	13.1	13.5	13.9	14.3
55	12.3	12.7	13.2	13.6	14.0	14.6	15.3
60	12.7	13.1	13.6	14.1	14.7	15.5	16.3
65	13.1	13.6	14.1	14.7	15.5	16.4	17.2
70	13.5	14.1	14.6	15.5	16.4	17.3	18.2
75	--	14.6	15.4	16.3	17.2	18.2	19.1
80	--	--	16.1	17.1	18.1	19.1	20.0
----- Years -----							
Merging age	--	--	72	64	58	54	50

Up to merging age:

$$\begin{aligned} \text{Diameter of average tree} = & 11.33 - 0.0668(\text{age}) + 0.000705(\text{age})^2 \\ & - 0.0101(\text{site index}) \\ & + 0.000950(\text{site index})(\text{age}). \end{aligned}$$

Above merging age:

$$\begin{aligned} \text{Diameter of average tree} = & 1.09 + 0.1057(\text{age}) - 0.000198(\text{age})^2 \\ & + 0.0247(\text{site index}) \\ & + 0.000911(\text{site index})(\text{age}). \end{aligned}$$

$$\text{Merging age} = 173.5 - 1.775(\text{site index}) + 0.00625(\text{site index})^2.$$

FIGURE 8

Basal area per acre--trees
larger than 0.5 inch d.b.h.

BASAL AREA

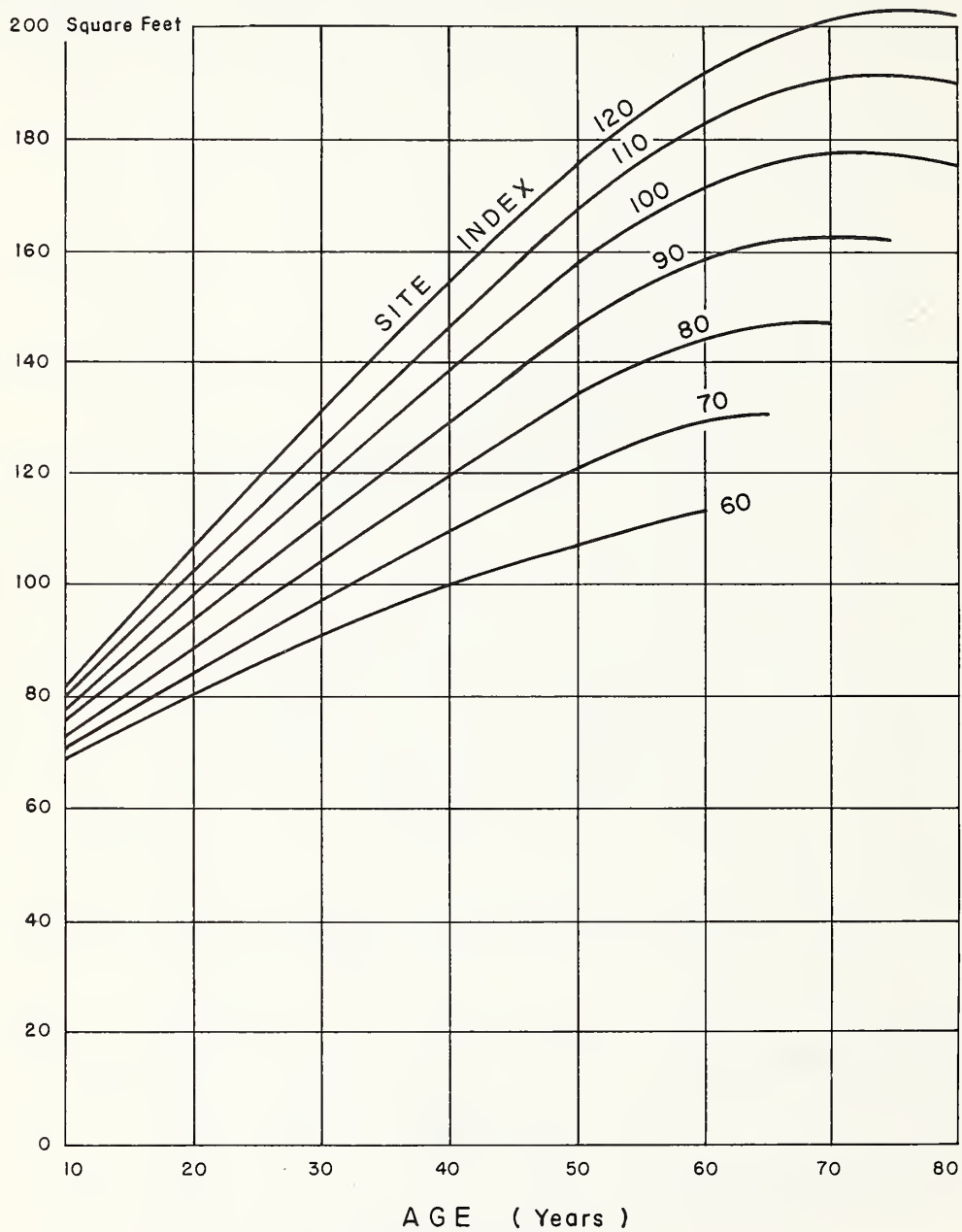


TABLE 8

Basal area per acre--trees
larger than 0.5 inch d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- <u>Square feet</u> -----							
10	69	71	73	76	78	80	82
15	75	78	82	85	88	92	95
20	80	85	89	94	98	103	107
25	86	91	97	103	108	114	119
30	91	97	104	111	118	124	131
35	95	103	111	119	127	135	142
40	99	108	117	127	136	144	153
45	103	114	126	137	147	156	164
50	107	120	134	146	157	167	175
55	110	125	140	153	165	175	184
60	113	129	144	158	171	182	192
65	--	130	146	161	174	187	197
70	--	--	147	162	177	190	201
75	--	--	--	162	177	191	203
80	--	--	--	--	175	190	203
----- <u>Years</u> -----							
Merging age	--	51	45	41	40	41	45

Up to merging age:

$$\text{Basal area} = 56.16 - 0.006620(\text{age})^2 + 0.022465(\text{site index})(\text{age}).$$

Above merging age:

$$\begin{aligned} \text{Basal area} = & - 111.95 + 3.8354(\text{age}) - 0.037466(\text{age})^2 + 1.5606(\text{site index}) \\ & - 0.006747(\text{site index})^2 + 0.016438(\text{site index})(\text{age}). \end{aligned}$$

$$\text{Merging age} = 165.0 - 2.5(\text{site index}) + 0.0125(\text{site index})^2.$$

FIGURE 9

Basal area per acre--trees
larger than 5.5 inches d.b.h.

BASAL AREA

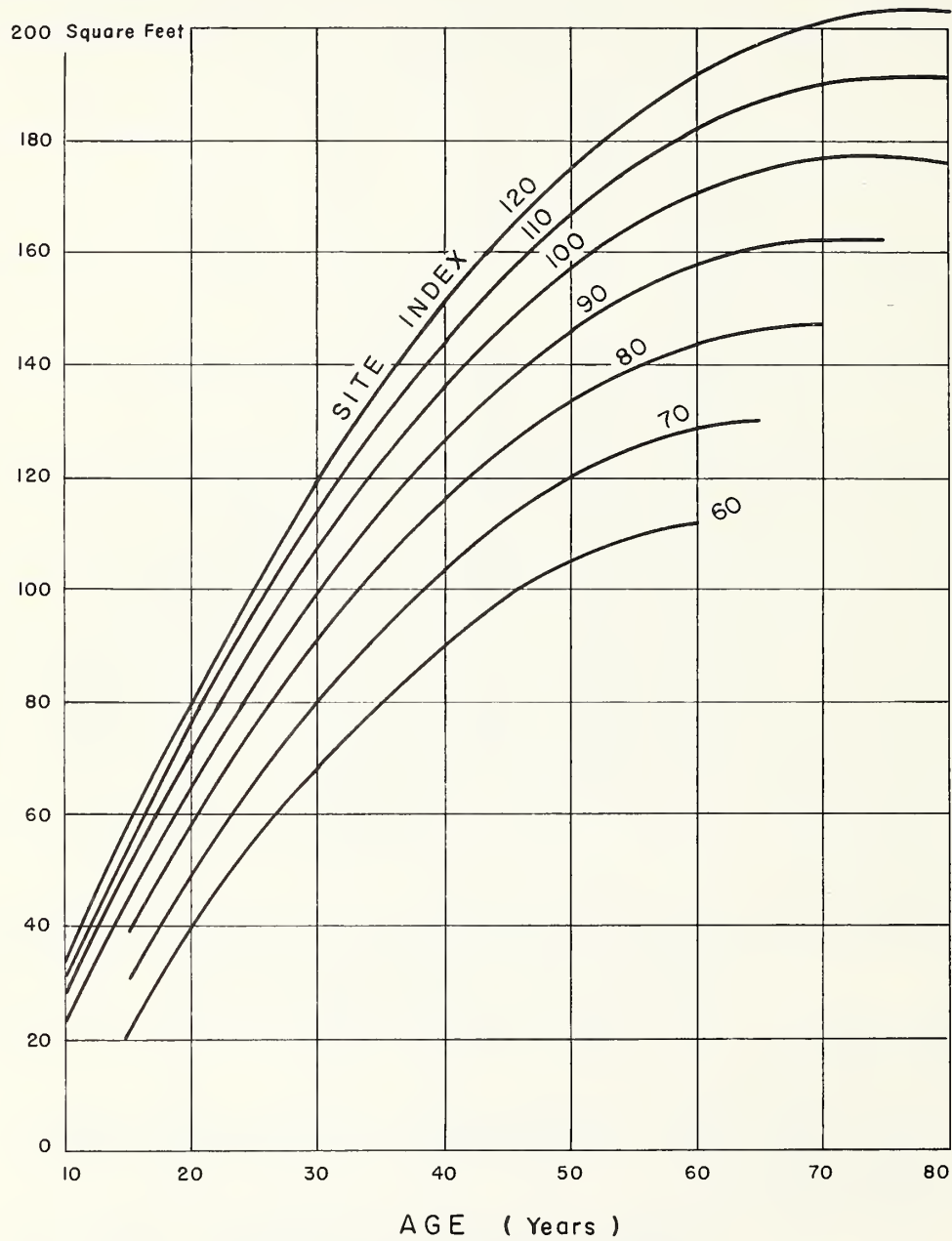


TABLE 9

Basal area per acre--trees
larger than 5.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- <u>Square feet</u> -----							
10	--	--	--	23	28	31	33
15	21	31	39	45	50	54	57
20	39	49	58	65	71	76	79
25	55	65	75	83	90	96	100
30	68	80	91	100	107	114	119
35	80	93	104	114	123	130	136
40	90	104	116	127	136	144	151
45	99	113	126	137	147	156	164
50	105	120	134	146	157	167	175
55	109	125	140	153	165	175	184
60	112	129	144	158	171	182	192
65	--	130	146	161	174	187	197
70	--	--	147	162	177	190	201
75	--	--	--	162	177	191	203
80	--	--	--	--	175	190	203

$$\begin{aligned}
 \text{Basal area} = & - 111.95 + 3.8354(\text{age}) - 0.037466(\text{age})^2 \\
 & + 1.5606(\text{site index}) - 0.006747(\text{site index})^2 \\
 & + 0.016438(\text{site index})(\text{age}).
 \end{aligned}$$

FIGURE 10

Basal area per acre--trees
larger than 9.5 inches d.b.h.

BASAL AREA

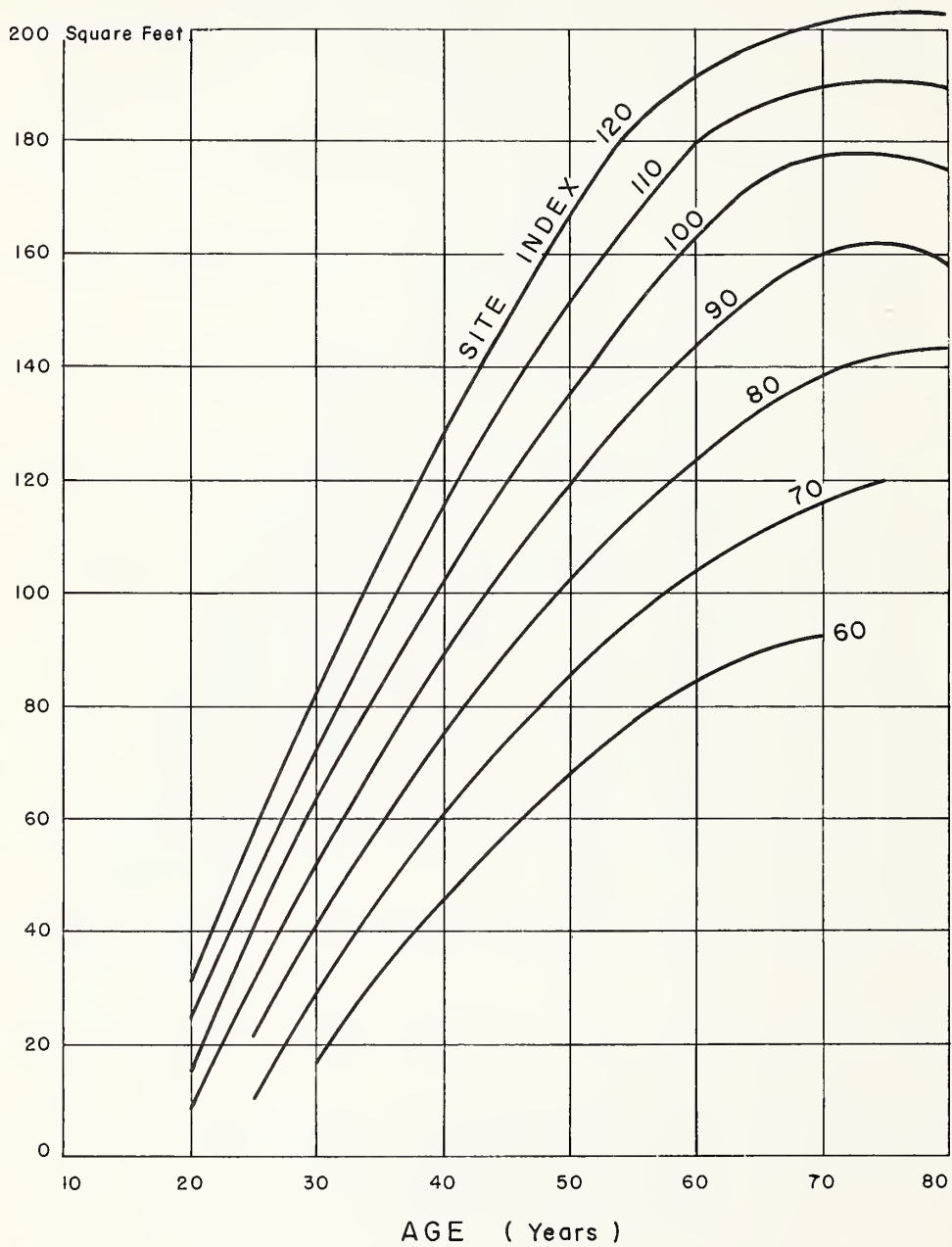


TABLE 10

Basal area per acre--trees
larger than 9.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- <u>Square feet</u> -----							
20	--	--	--	8	16	24	31
25	--	10	21	31	40	49	57
30	16	29	41	52	63	73	82
35	32	45	59	71	83	95	106
40	45	60	75	89	102	115	127
45	57	74	90	105	120	134	147
50	68	86	103	119	135	151	166
55	77	96	114	132	149	166	182
60	84	104	124	143	162	180	192
65	89	111	132	153	173	187	197
70	93	116	139	160	177	190	201
75	--	120	143	162	177	191	203
80	--	--	142	159	175	190	203
----- <u>Years</u> -----							
Merging age	--	--	--	75	70	65	60

Up to merging age:

$$\begin{aligned} \text{Basal area} = & - 150.64 + 3.6498(\text{age}) - 0.033070(\text{age})^2 \\ & + 0.8356(\text{site index}) - 0.002911(\text{site index})^2 \\ & + 0.026337(\text{site index})(\text{age}). \end{aligned}$$

Above merging age:

$$\begin{aligned} \text{Basal area} = & - 111.95 + 3.8354(\text{age}) - 0.037466(\text{age})^2 \\ & + 1.5606(\text{site index}) - 0.006747(\text{site index})^2 \\ & + 0.016438(\text{site index})(\text{age}). \end{aligned}$$

$$\text{Merging age} = 120.0 - 0.5(\text{site index}).$$

FIGURE 11

Cubic-foot volume per acre--trees
larger than 5.5 inches d.b.h.

VOLUME

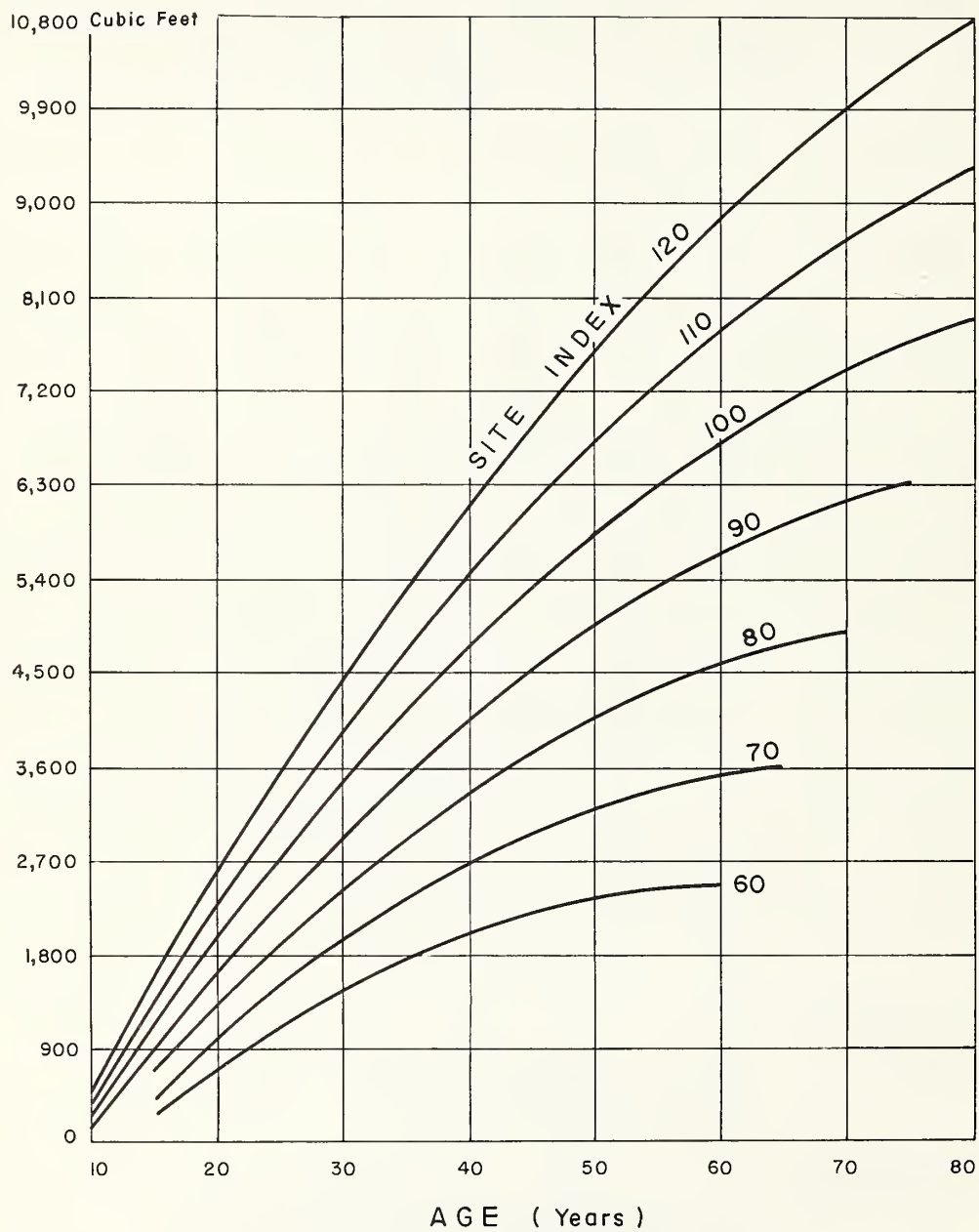


TABLE 11

Cubic-foot volume per acre--trees
larger than 5.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- Cubic feet -----							
10	--	--	--	120	240	350	470
15	260	470	680	900	1,110	1,320	1,530
20	700	1,010	1,320	1,620	1,930	2,240	2,540
25	1,100	1,500	1,900	2,300	2,700	3,100	3,500
30	1,440	1,940	2,430	2,930	3,420	3,920	4,410
35	1,740	2,320	2,910	3,500	4,090	4,680	5,270
40	1,980	2,660	3,350	4,030	4,720	5,400	6,080
45	2,170	2,950	3,730	4,510	5,290	6,070	6,840
50	2,320	3,190	4,060	4,940	5,810	6,680	7,560
55	2,410	3,380	4,350	5,320	6,280	7,250	8,220
60	2,460	3,520	4,580	5,640	6,710	7,770	8,830
65	--	3,610	4,770	5,920	7,080	8,240	9,390
70	--	--	4,900	6,150	7,400	8,650	9,900
75	--	--	--	6,330	7,680	9,020	10,360
80	--	--	--	--	7,900	9,340	10,780

$$\begin{aligned} \text{Cubic feet} = & - 949.13 + 10.4598(\text{age}) - 0.996486(\text{age})^2 \\ & - 7.0681(\text{site index}) + 1.886911(\text{site index})(\text{age}). \end{aligned}$$

Tree volume is for stem to a 4-inch top d.i.b., stump excluded. (From Table 93, "Volume Tables for Pacific Northwest Trees," compiled by F. A. Johnson, U.S. Dept. Agr. Handb. 92, 122 tables. 1955.)

FIGURE 12

Cubic-foot volume per acre--trees
larger than 9.5 inches d.b.h.

VOLUME

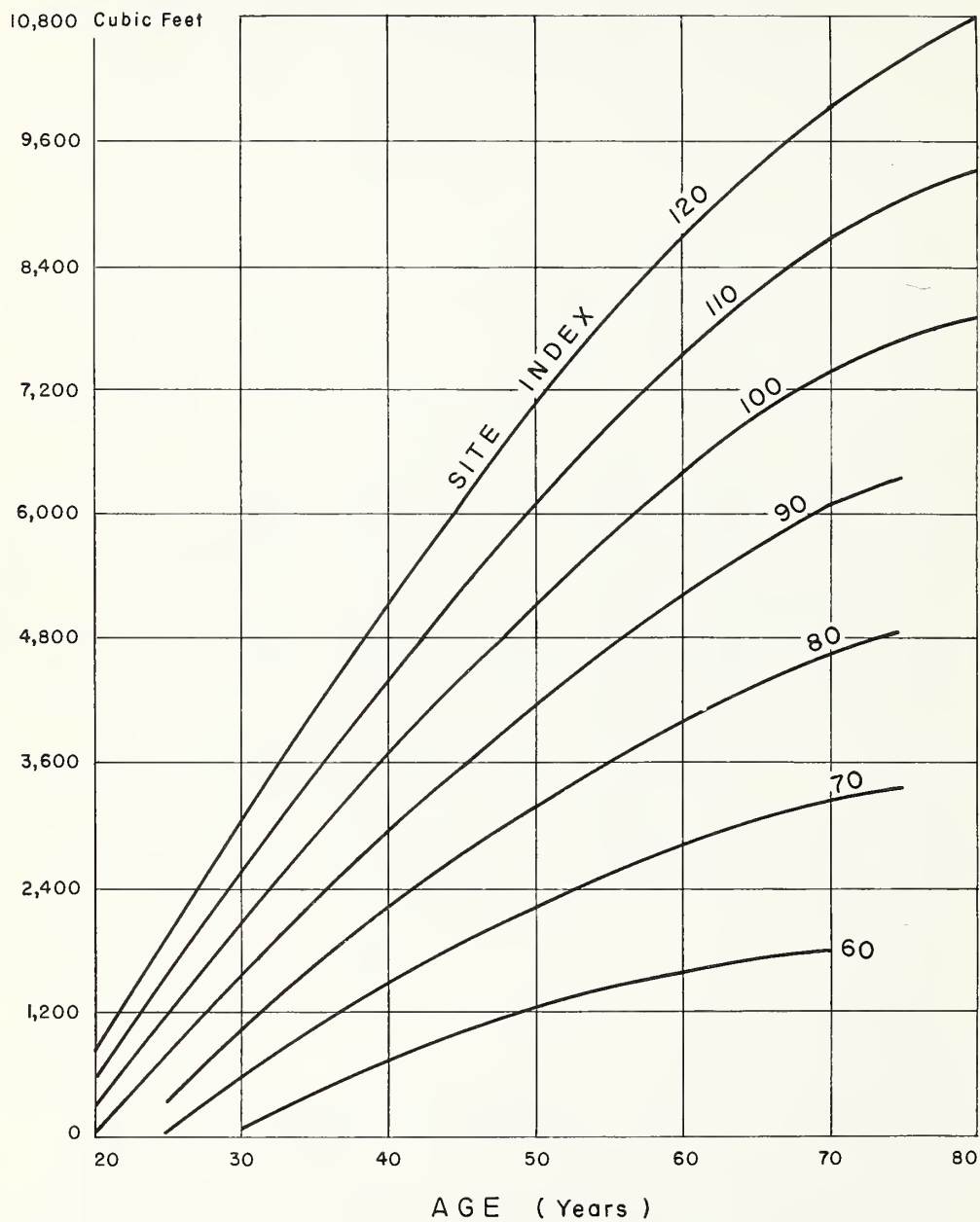


TABLE 12

Cubic-foot volume per acre--trees
larger than 9.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- Cubic feet -----							
20	--	--	--	30	300	560	820
25	--	50	440	820	1,200	1,580	1,960
30	70	570	1,070	1,560	2,060	2,560	3,060
35	430	1,040	1,660	2,270	2,880	3,500	4,110
40	740	1,470	2,200	2,940	3,660	4,400	5,130
45	1,020	1,870	2,710	3,560	4,410	5,250	6,100
50	1,250	2,220	3,180	4,140	5,110	6,070	7,030
55	1,450	2,530	3,610	4,690	5,770	6,850	7,920
60	1,600	2,800	3,990	5,190	6,390	7,580	8,830
65	1,710	3,030	4,340	5,650	6,960	8,240	9,390
70	1,790	3,220	4,640	6,070	7,400	8,650	9,900
75	--	3,360	4,910	6,330	7,680	9,020	10,360
80	--	--	--	--	7,900	9,340	10,780
----- Years -----							
Merging age	--	--	--	75	70	65	60

Up to merging age:

$$\begin{aligned} \text{Cubic feet} = & - 1711.81 - 15.7088(\text{age}) - 0.811366(\text{age})^2 \\ & - 20.1181(\text{site index}) + 2.328763(\text{site index})(\text{age}). \end{aligned}$$

Above merging age:

$$\begin{aligned} \text{Cubic feet} = & - 949.13 + 10.4598(\text{age}) - 0.996486(\text{age})^2 \\ & - 7.0681(\text{site index}) + 1.886911(\text{site index})(\text{age}). \end{aligned}$$

Tree volume is for stem to a 4-inch top d.i.b., stump excluded. (From Table 93, "Volume Tables for Pacific Northwest Trees," compiled by F. A. Johnson, U.S. Dept. Agr. Handb. 92, 122 tables. 1955.)

$$\text{Merging age} = 120.0 - 0.5(\text{site index}).$$

FIGURE 13

Board-foot volume per acre (Scribner rule)--
trees larger than 9.5 inches d.b.h.

VOLUME

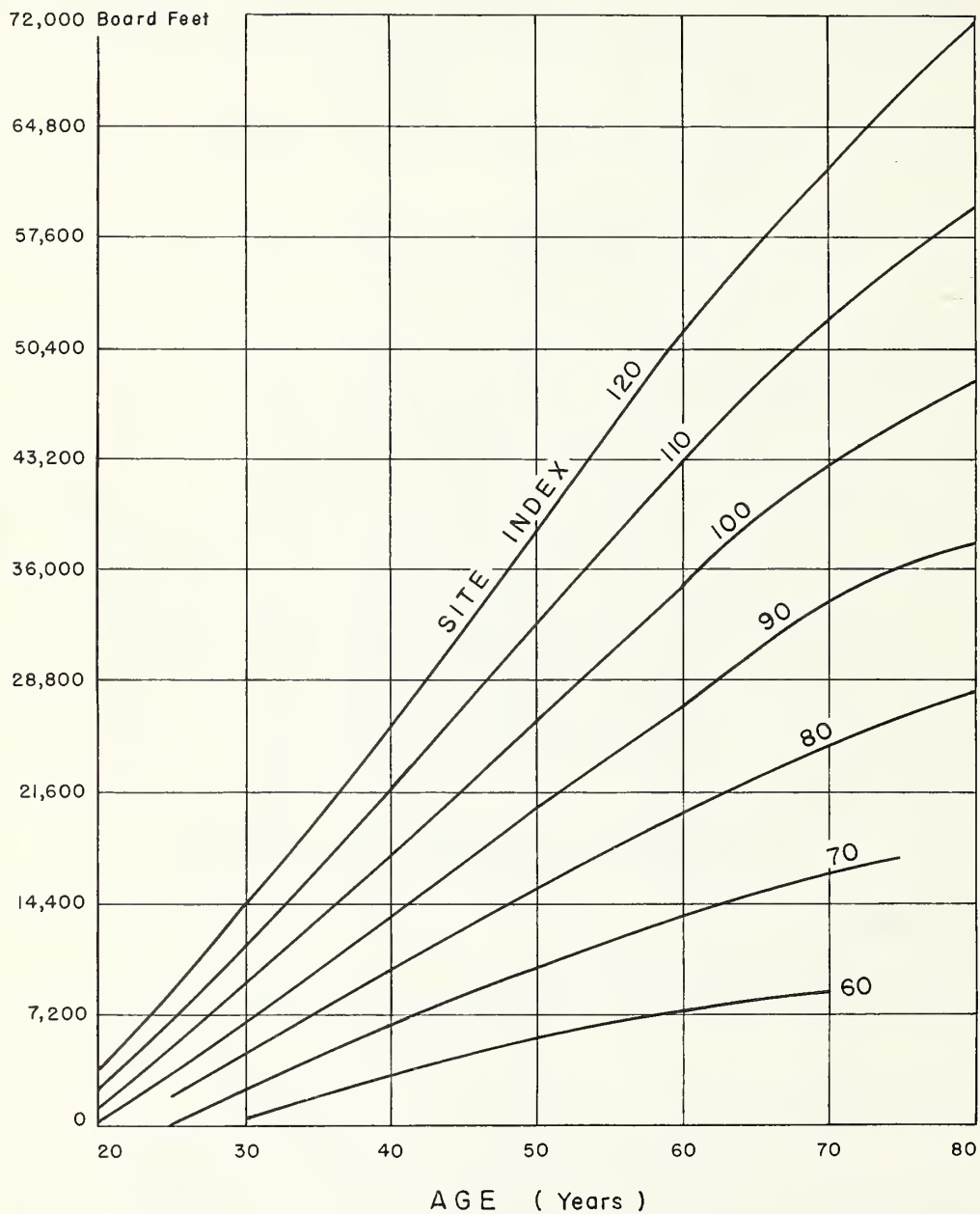


TABLE 13

Board-foot volume per acre (Scribner rule)--
trees larger than 9.5 inches d.b.h.

Age (years)	Site index (feet)						
	60	70	80	90	100	110	120
----- <u>Board feet</u> -----							
20	--	--	--	100	1,200	2,400	3,500
25	--	200	1,800	3,500	5,200	6,900	8,800
30	300	2,400	4,600	6,800	9,200	11,700	14,300
35	1,800	4,500	7,300	10,300	13,400	16,600	20,000
40	3,200	6,500	10,000	13,700	17,600	21,700	26,000
45	4,500	8,400	12,700	17,100	21,900	26,900	32,100
50	5,600	10,300	15,300	20,600	26,200	32,100	38,400
55	6,600	12,000	17,800	24,000	30,500	37,500	44,800
60	7,500	13,600	20,200	27,300	34,900	42,900	51,700
65	8,200	15,100	22,500	30,600	39,200	48,100	56,800
70	8,700	16,400	24,700	33,800	42,800	52,100	61,900
75	--	17,500	26,800	36,100	45,700	55,900	66,800
80	--	--	28,100	37,800	48,300	59,600	71,600
----- <u>Years</u> -----							
Merging age	--	--	--	75	70	65	60

Up to merging age:

$$\begin{aligned} \text{Board feet} = & - 5964.07 - 70.0932(\text{site index}) \\ & - \text{age}[54.7306 - 7.550025(\text{site index}) \\ & + 0.006623(\text{site index})^2] - \text{age}^2[2.826865 \\ & + 0.005172(\text{site index}) - 0.000767(\text{site index})^2] \\ & - \text{age}^3[0.000267(\text{site index})]. \end{aligned}$$

Above merging age:

$$\begin{aligned} \text{Board feet} = & - 3306.85 - 24.6260(\text{site index}) \\ & + \text{age}[36.4429 + 6.261671(\text{site index}) \\ & - 0.002327(\text{site index})^2] - \text{age}^2[3.471836 \\ & - 0.003444(\text{site index}) - 0.000621(\text{site index})^2] \\ & - \text{age}^3[0.000328(\text{site index})]. \end{aligned}$$

Tree volume is for stem to an 8-inch top d.i.b., stump excluded. Logs scaled in 8-foot lengths. (From Table 97, "Volume Tables for Pacific Northwest Trees," compiled by F. A. Johnson, U.S. Dept. Agr. Handb. 92, 122 tables. 1955.)

$$\text{Merging age} = 120.0 - 0.5(\text{site index}).$$

